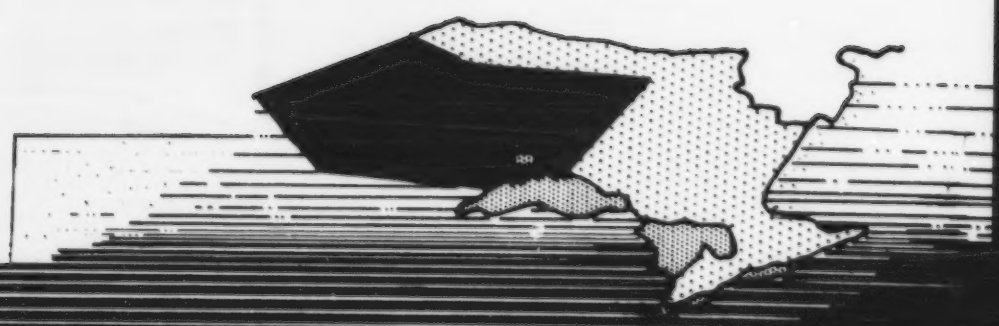

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DIRECT SEEDING BLACK SPRUCE IN NORTHWESTERN ONTARIO

by

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ABSTRACT

Direct seeding of black spruce (Picea mariana (Mill) B.S.P.) in northwestern Ontario can be an important and valuable reforestation technique, although it currently plays a very minor role in black spruce regeneration. The main factors influencing the establishment of direct-sown black spruce are the amount of receptive seedbeds and their water relations. The most receptive upland seedbeds consist of mineral soil-humus mixtures. Deeply site prepared mineral soils and the feather mosses are poor seedbeds. On lowland organic sites, direct seeding should be considered on the sphagnum moss - rich areas. Various methods of site preparation, application rates and seeding methods are compared and discussed. Potential sites conducive to black spruce seed germination, establishment and growth are identified using the Forest Ecosystem Classification (FEC) system.

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INTRODUCTION

Black spruce (Picea mariana (Mill) B.S.P.) is one of the most important commercial tree species in northwestern Ontario. Its long, flexible fibers and superior pulping qualities make it the preferred raw material for a number of pulp and paper companies in the region. Black spruce exists on a wide range of ecological sites which require different silvicultural prescriptions for successful stand establishment. An effective, inexpensive method is required to regenerate black spruce on these various sites after harvesting in order to provide sufficient raw material for the forest industry in the future.

Currently, black spruce direct seeding plays a very minor role in the regeneration of the species, but some successes have been reported[1]. Hand planting of bareroot and container stock has been the most common method of regenerating black spruce in the past; however, the amount of area that can be planted in the future may be limited by unsuitable site conditions, high costs, and labour shortages (Fraser 1980a; Wood and Jeglum 1984; Fleming et al. 1987). Planting should be restricted to the better sites offering the highest potential dollar return on investment (ie. prime sites) (Jeglum 1987). Seeding and other initial lower cost regeneration methods (ie. seed tree, modified harvest cutting, scarification for natural regeneration, preservation of advanced growth) are viable

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[1] Andison, D. 1988. Personal communications. Survey of artificially regenerated sites data base. Ont. Min. of Nat. Res., Toronto, Ont.

alternatives for regenerating many of the poorer, less accessible and less intensively managed sites.

Before black spruce seeding can become an operational reforestation technique, the forest manager must recognize the germination requirements of black spruce and subsequent conditions necessary for seedling establishment and growth and be able to create these conditions on the available sites.

The intent of this literature review is to make the reader aware of the requirements for germination, establishment and growth of black spruce, to examine where direct seeding is feasible, to determine appropriate seedbed preparation, and to review current seeding methods.

CRITICAL FACTORS FOR SUCCESS

The main factors influencing the establishment of direct-sown black spruce are the availability of receptive seedbeds, seedbed water and temperature relations, light and predation by rodents.

Surface temperatures, either too high or too low, contribute to poor seed germination and high seedling mortality (Place 1985; Day 1963; Scott 1970; Richardson 1971; Arnott 1974; Stiell 1976; Wood and Raper 1987). Temperatures between 15^0C and 30^0C are optimum for the germination of conifer seed (Baker 1950). Cold temperatures inhibit germination. Heat dries the surface of the seedbed causing drying of the recently imbibed seed or high

transpirational stress in newly germinated seedlings (Arnott 1974). Fraser (1970) has published detailed information on cricital temperatures for germination.

The water relations of the seedbed is the most important factor governing black spruce seedling survival and establishment after germination (LeBarron 1944; Leslie 1953; Place 1955; Smith 1962; Arnott 1974; Richardson 1974; Rudolph 1974; Jeglum 1979; Fleming and Groot 1984). Adequate supplies of moisture are generally present in the spring but as temperature and evapotranspiration increase, deficiencies of surface moisture can cause mortality in newly germinated seedlings. Black spruce seed can go through numerous cycles of drying and wetting without damage but as soon as the radicle emerges, tolerance to drying decreases rapidly (Thomas and Wein 1985). Too much water reduces oxygen availability and can cause mortality through flooding or washing the seedling from its microsite.

Shade improves germination by reducing temperature and moisture fluctuations but may not be optimum for seedling growth. Shade can be provided by slash, vegetation or sowing on the north side of the furrow.

Seed loss to rodents can be a major impediment to establishing black spruce stands by seeding. A thin soil cover reduces the problem somewhat.

Receptive seedbeds for black spruce vary with ecological site type ie. upland, lowland. The seedbed type and its influence on

seed germination and seedling growth will be discussed below by the two main site conditions - upland and lowland.

Seedbed Types

Mineral Soil - (Uplands)

A mixture of mineral soil and humus is best for seedling survival and growth on upland sites (Place 1955; Linteau 1957; Winston 1975). As well as improving the physical properties of the soil, such as water infiltration and aeration, the nutrient levels will be greater in the mixture than in mineral soil alone (Linteau 1957). A mixture of mineral soil and humus helps to retain the moisture necessary for the survival of the lateral spreading root systems of black spruce during drier summer months (Neily 1980) and subjects the seedling to fewer extremes of temperature.

Fleming and Groot (1984) found that successful germination occurred when the seed was between 5 cm above and 10 cm below the mineral soil-humus interface. The soil horizons included are the H, Hi, Ah, F, Ae and B horizons, or any mixture thereof (Fleming et al. 1987). In another study, Winston (1975) showed that the survival and growth of black spruce was best when the seed was sown on the nutrient-rich Ah layer.

Mineral soil has frequently been cited as an excellent seedbed for the germination of black spruce (LeBarron 1944; Jarvis and Cayford 1961; Vincent 1965; Arnott 1974; Fraser 1975; Jeglum 1979; Wood and Jeglum 1984) because of its water infiltration, aeration, and heat conducting capacities. However,

bare mineral soil is not ideal for seed germination and seedling survival because of the dangers of frost heaving and drought (Neily 1980). Both can be modified by shading or leaving some cover on the site.

Vincent (1965) noted that soils of medium texture are usually favourable seedbeds if the water table is close enough to the surface to maintain capillary connection with it, but warned of excessive frost heaving of exposed soil. According to Neily (1980), the soils most prone to frost heaving are heavy-textured soils, imperfectly drained soils and soils compacted by heavy machinery. Conversely, LeBarron (1944) found that seedling mortality from heat was lowest on mineral and scarified soil and highest on burned duff. Baker (1950) and Place (1955) confirmed that duff will heat up much more than mineral soil.

Feather moss (Pleurozium spp.) was found to be a moderately receptive seedbed on shallow-soil uplands when it was compacted and protected from excessive drying by the leave strips in a modified cut near Nipigon, Ontario (Jeglum 1984). In most cases, it is not recommended as a seedbed because of rapid drying.

For seedling growth it appears that a mix of organic and mineral provides optimum nutrient supply. Clay soil should provide the best nutrition of the mineral soils, but the density of the clay, and its coolness owing to moisture retention, probably disallow optimum root growth. Silty soils and very fine sandy loams may provide optimum root growth media, being between coarse sands and heavy clays.

Organic Soil - (Lowlands)

Lowland seedbeds are composed of living mosses or organic matter in various stages of decomposition (Fleming and Groot 1984). The germination and establishment of black spruce on moss seedbeds has been studied by numerous authors.

The sphagnum mosses are widely recognized as some of the most favourable seedbeds for the germination of black spruce seed (LeBarron 1948; Heinselman 1957; Vincent 1965; Arnott 1974; Richardson 1974; Jeglum 1981; Fleming and Groot 1984). This is attributed to the excellent water supplying capabilities of this moss type. The main disadvantage of sphagnum seedbeds is the tendency of the rapidly growing types to engulf seedlings (LeBarron 1948; Roe 1949; Place 1955; Vincent 1965; Arnott 1968). In a Minnesota study, Heinselman (1957) found sphagnum seedbeds supported 85% of the regeneration, and that the advantages of this seedbed type far outweighed the deleterious effects of smothering. Roe (1949) suggested seedling mortality due to smothering by sphagnum could be reduced by sowing the black spruce seed earlier to produce larger seedlings by the time the moss begins active growth.

Seedling germination and survival on sphagnum seedbeds can also be improved by compaction. Compaction prevents deep penetration of seeds into the mat, improves the moisture holding capacity of the moss, and retards sphagnum growth to allow time for the seedlings to become established (Arnott 1968; Jeglum 1979). A certain degree of sphagnum compaction does occur through

mechanized logging or scarification disturbances on these sites. Recently, some trials have been done with tracked vehicles for improving compaction. Shear blading in the early winter also serves to compact sphagnum and other organic material if the ground surface is not frozen, or only shallowly frozen.

Feather moss is a poor seedbed for black spruce germination (Jeglum 1979) because it dries out and dies after the protective forest cover has been removed (Place 1955; Vincent 1966; Fleming and Groot 1984; Wood and Jeglum 1984). In a greenhouse study, Jeglum (1979) found that the feather moss, Pleurozium schreberi, was the poorest seedbed for germination when compared to three sphagnum taxa, sand, clay, humus-covered sand and humus-covered clay. He attributed this to its poor water-retaining and water-supplying capacity. Feather moss's loose structure allows for easy passage of air and rapid drying.

Sphagnum mosses clearly provide a greater receptive seedbed potential than feather moss for the establishment of black spruce through direct seeding. Once established, black spruce may grow better on feather moss sites (Arnott 1968) because of their superior nutrient supply, especially of nitrogen (Jeglum 1979).

Well decomposed organic matter (dark peat), exposed by harvesting-scarification disturbances, provides a good seedbed for germination; however, poor seedling survival is common due to severe grass and sedge competition, flooding, erosion and frost heaving (Fleming and Groot 1984; Jeglum 1984; Wood and Jeglum 1984).

Seedbed Preparation

The quality of seedbed preparation for black spruce is very important in the successful regeneration of black spruce by seeding; site preparation is instrumental in seeding success. It is recommended that proper seedbed preparation i.e. soil disturbance, occur on a minimum of 40 % of the total area treated for direct seeding (Arlidge 1967; Brown 1974; Hellum 1974). It may be that as the amount of receptive seedbed increases the seeding rate required to achieve successful establishment decreases (Jeglum 1988 pers. comm.) Again, the different requirements for each site type are discussed below.

Uplands

On upland sites, site preparation is required prior to direct seeding black spruce. This can be achieved through prescribed burning, chemical or mechanical site preparation (Leslie 1953), although mechanical site preparation is most common. The object of seedbed preparation for black spruce on upland soils is to mix the mineral soil and humus horizons. This will not only produce a good seedbed but may also reduce competing vegetation.

Nearly all of the scarifiers currently on the market fail to produce a receptive black spruce seedbed. In a recent trial (Fleming et al. 1987), seven scarifiers were evaluated for productivity and ability to produce receptive black spruce seedbeds on upland sites. The modified C and H plow, followed by the CFS row scarifier, produced the most receptive seedbeds. The TTS disc

trencher was thought to have the greatest potential for improvement. Hydraulic downpressure and/or powered disc rotation were recommended as ways of increasing seedbed exposure. The mini-barrels and chains offer little room for improvement as the depth of scarification cannot be readily controlled or quickly changed. Failure of some upland direct seeding trials has been attributed to improper and inadequate site preparation using barrels and chains (Fraser 1981a).

Although the Bracke scarifier-seeder can be an effective tool for regenerating jack pine (Pinus banksiana Lamb.) (Winston and Schneider 1977; Sidders 1985), the results of black spruce seeding at the time of site preparation using the Bracke has been poor. The most common reason for failure appears to be flooding and washing on the moist sites where the scalps are too deep (Winston 1975; Winston and Scheider 1977). Scalp depth and seed release position can be adjusted (Parker 1972), but it has yet to be seen whether the Bracke or Bracke Badger will be able to consistently produce favourable black spruce seedbeds on rugged upland sites.

Prescribed burning on upland sites can reduce competition and expose a favourable seedbed. However, prescribed fires are not always hot enough to consume the organic layers, as they are not usually applied in high-hazard weather (Johnson 1956; Stiell 1976). In Newfoundland, Richardson (1969,1981) has reported some successes when seeding on burned-over areas; however, Newfoundland's maritime climate is probably more conducive to black spruce establishment

as there is adequate and well distributed rainfall along with cool, moist air. In Ontario, McRae (1985) found no significant difference in stocking when comparing burned areas with those site prepared using barrels and chains or Young's Teeth. This indicates potential for the use of prescribed burning as a site preparation option for upland black spruce seeding.

On upland sites, no site preparation method has been effective for black spruce seeding to date. As a result, most agencies are still planting upland sites.

Lowlands

The options for site preparation on lowland black spruce organic sites are limited. Many of these sites are sphagnum-rich, and site preparation may not be required. Harvesting with wide-tired machines can reduce the ground disturbance (rutting, flooding, impeded drainage) normally associated with conventional tires and will improve the sphagnum seedbed through compaction (Fleming and Groot 1984). In other cases, slash removal may be all that is required to expose the natural seedbed. Full-tree logging is often cited as an obvious solution (Johnston 1975; Jeglum 1984; Fleming and Groot 1984) as well as an efficient method of cone aggregation and collection (Haavisto 1979), although it removes the natural seed source from the site. Full-tree logging will permit improved seedbed production by scarification machinery; or expose natural seedbeds already in existence on most lowland sites.

Winter shear blading on peatland sites has been successful in recent years (Haavisto 1979; Jeglum 1979; Fleming and Groot 1984). The object is to plow the slash aside and shear off the living moss to create a favourable seedbed (Haavisto 1979). The effectiveness of winter shear blading in relation to other site preparation techniques is encouraging but the costs are high.

The preservation of advanced growth is also being recognized as a valid regeneration method, especially on wet nutrient-poor, sphagnum-rich sites (Haavisto 1979; Fleming and Groot 1984; Groot 1984).

Prescribed fire on organic sites has proven to be an effective method of reducing slash and litter, thereby increasing the amount and distribution of regeneration (Roe 1949; Heinselman 1957). Johnston (1975) found the initial establishment of spruce after burning to be good, but warns of brush competition soon afterwards. On brushy lowlands, the major requirement for successful direct seeding of black spruce is the reduction of vegetation regrowth, rather than seedbed preparation (Johnston 1972).

Fire will reduce the drier layers of moss (ie. feather moss) and scorch the living sphagnum, thus increasing the amount of suitable seedbed (Fleming and Groot 1984). In the greenhouse, Jeglum (1979) found burned sphagnum surfaces provided good growth for the spruce seedlings, but burned feather moss showed reductions in both root and shoot growth. He suggested deeper burning to expose the more decomposed humus layers. For example in Manitoba, Chrosciewicz (1976) found that moderate burns in lowland black

spruce were more beneficial for seedling establishment than light burns. Further investigation into different burning intensities on specific site types to maximize seedbed receptivity are warranted.

On lowland sites where some form of site preparation may be required, both prescribed burning and winter shear blading have been effective for black spruce seedbed establishment for seeding.

OTHER FACTORS

Seeding Rates and Methods

Black spruce may be broadcast (aerial, ground) seeded, spot seeded, row seeded or shelter cone seeded.

Black spruce broadcast seeding results have been very inconsistent and this method is not considered operational in northwestern Ontario. This technique may not become operational in the near future due to the great quantities of black spruce seed required. Aerial seeding rates have averaged 100,000 to 300,000 seeds per ha. Frisque (1975) concluded that spring seeding of black spruce at a rate of 276,650 per ha gave good results based on a fifth year assessment. Richardson (1974) and Brown (1974) suggest that 250,000 to 500,000 viable seeds per hectare of black spruce are required to produce full stocking with broadcast seeding after 40% mechanical scarification. On lowland sites Spruce Falls Power and Paper Co. in Northern Region usually seed black spruce at a rate of 100,000 seeds per ha but in a split application of 50,000 seeds in two consecutive years.

Black spruce aerial seeding success is also influenced by seed distribution pattern. Fleming et al. (1985) made recommendations for controlling seed distribution patterns in operational black spruce seeding with a Brohm seeder/piper PA-18A aircraft combination. Spruce Falls Power and Paper have designed and developed a black spruce aerial seeding device which is used with a helicopter.

With broadcast seeding many seeds fall on unreceptive beds resulting in seed wastage (Leslie 1953; Smithers 1964; Scott 1970; Hellum 1974; Stiell 1976). The quantity of black spruce seed needed to regenerate annual depletions and backlogged areas by this method is enormous when compared to our current seed inventories, collection practices and poor cone crops (Haavisto 1980). Assuming a seeding rate of 100,000 seed per ha, it would require a 0.3 hl of cones per ha seeded.

Row seeding is a relatively new concept and still in the developmental stage, at least for black spruce. Combining scarification and seeding in one operation is an attractive prospect. Work is currently underway to combine a precision seeder with the TTS power disc trencher. If the proper black spruce seedbed can be prepared, this method of row seeding may be of importance in northwestern Ontario in the future.

Spot seeding can result in higher stocking, improved seed utilization and stands with fairly uniform spacing when compared to broadcast-sown areas (Scott 1970; Stiell 1976; Neily 1980). Fraser (1981b) noted that this method should ensure better

microsite selection thereby increasing germination and seedling establishment. When sowing on spots or scalps, minimal site preparation disturbances can reduce costs (Smithers 1964; Stiell 1976). Germination from spot seeding can be improved by ensuring the seeds are firmly in contact with the growing medium i.e. tamping or stepping on the seed, immediately after they are sown.

Spot seeding has the obvious tendency to produce seedlings in clumps (Scott 1970; Stiell 1976) but the results of some trials indicate a trend towards early dominance by one of the trees (Pike 1987). Neily (1980) suggested that the cost of cleaning was less on spot seeded areas than on areas which were broadcast seeded; however, if clustering is a problem, tending costs could escalate.

The use of shelter cones for spot seeding is proving to be reliable for regenerating black spruce on upland sites. The shelter cone acts as a mini-greenhouse, promoting optimum temperature and moisture conditions for germination and establishment (Murray and Borland 1981; Reinholt 1983; Wood and Jeglum 1984; Horvath 1985; Dominy and Wood 1986; Putman and Zasada 1986; Pike 1987). Hagner and Sahlen (1976) found that the shelter cone also protected germinating seeds from temperature extremes, drought, birds and rodents, frost heaving and damage from litter. Best results have occurred on compacted upland microsites free of litter and humus, when no air gaps were left around the edge of the cone (Hagner and Sahlen 1976). Shelter cone seeding on a feather moss site has resulted in poor stocking, whereas mineral and sphagnum sites have produced good stocking (Wood and Jeglum 1984).

Vegetative competition is a major constraint when using the shelter cone system. Areas to be seeded should be upland sites which offer little competition. Wood and Jeglum (1984) suggest that both competition and flooding can reduce the effectiveness of this method on lowland sites.

The seeding rate with shelter cones should be 4 to 6 viable black spruce seeds per cone. Harrison (1988) found that 6 seeds per cone were sufficient, producing an average stocking of 98%. Similarly, Horvath (1985) found sowing three seeds per shelter in May achieved 89% stocking, whereas 6 seeds produced 94%.

Shelter seeding is operationally much like planting but it lowers regeneration costs initially by eliminating the nursery phase (Basaraba 1983; Pike 1987). The shelter cone system is considered to be a viable regeneration technique on upland sites, and further trials to determine the optimum sites, seeding rates, time of sowing and cone type are currently underway in northwestern Ontario.

The small size of black spruce seed makes control of seeding rates difficult. To ensure consistency, seeding tools must be redesigned or the seed must be pelletized.

Pelletization is a process where seeds are coated with a substance to give the seed a spherical form. Fraser and Adams (1980) and Harrison (1988) examined the influences of pelletization on the germination of black spruce seeds. They found the Moran-Coat process delayed germination marginally, but had no adverse effects on black spruce seedling development. They concluded that the

Moran-Coat pelletization of black spruce seed is an acceptable practice and produces the best germination results over other pelletization processes tested.

The possibility of seeding a mixture of black spruce and jack pine has been suggested (Wood and Raper 1987). On a mosaic of shallow soils, using a mixture of species may be the best option, so that the moister sites will favour black spruce, the drier sites jack pine.

There is no definitive formula for determining the optimum seeding rate. Suitable application rates are dependent upon a myriad of factors, the most important being the availability of favourable seedbeds. Riley (1975) and Rudolph (1974) note that the application rate can be decreased with increased seedbed preparation.

In the future, probabilistic models may be developed for relating black spruce stocking to the degree of scarification and seeding rate, as Regniere (1982) has done for jack pine. For the present, foresters must consider site, local climate conditions, and scarification and seeding techniques to determine an adequate seeding rate for black spruce.

When to Seed

Sowing should commence soon after a site is prepared (Stiell 1976; Neily 1980), although the literature is inconclusive as to how soon. In British Columbia, Arlidge (1976) found that successful spruce seeding decreased with time from site preparation, mainly

due to vegetation regrowth. He concluded that treated areas should be seeded the same year, and not later than one growing season after site preparation. In northwestern Ontario, Brown (1974) found consistently poor stocking (<30%) if sowing was done less than one month after site preparation, but stocking increased (to 69-85%) for areas seeded one to two months after site preparation. Rudolph (1974) believed that scarified areas should be left for one complete year to minimize the effects of soil settling and Hellum (1974) contends that seedbeds produced by scarification remain effective for up to four years.

The optimum leave time between site preparation and sowing is a function of site and the type and/or degree of scarification disturbance. When planning a seeding operation forest managers must take these factors into account.

The seeding of black spruce should occur early in the spring (April or May in northwestern Ontario) or as late into the fall as possible. Using shelter cones, Horvath (1985) found a late May sowing date produced the best stocking results (90%) for black spruce. Early May seeding dates were also reported to produce the best black spruce height growth (Harrison 1988).

Black spruce seeds lose their ability to germinate between ten and sixteen months after seeding on mineral soil (Fraser 1976; 1980b). Areas that are not acceptably stocked one year after seeding should be re-seeded unless there is a natural seed source nearby. Johnson (1973) concluded that seeding should not be viewed as a 'one shot' method, and recommends close surveillance for the

first few years. Neily (1980) cautions that the reason for failure must be determined before repeated applications of seed. If none are apparent, it may be that the site cannot be adequately regenerated by seeding and another method should be considered.

Vegetative Competition

Seeding should not be attempted on upland areas with a rich shrub layer because of the potential for rapid influx of competing vegetation. Nor should seeding be done on exposed peat and muck on organic sites which have the potential for rapid invasion of grass, sedge or alder (Alnus spp.) (Jeglum 1984; Wood and Jeglum 1984). Although shading vegetation may be initially beneficial to black spruce establishment by reducing soil temperature and moisture loss in summer, it will eventually compete with the seedlings for light, moisture, nutrients and space. Release will be necessary before the conifers are suppressed and mortality occurs.

Climate

Climatic factors may cause the complete failure of a seeding project, even when all other conditions are optimal (Neily 1980). Sowing should be initiated when the necessary moisture and temperature conditions are most likely to be met.

Northwestern Ontario experiences a humid to sub-humid macroclimate (Zoltai 1965); however, major differences exist between North Central (NC) and Northwestern (NW) Regions. These

differences are reflected in the climatograms that have been developed using climatic data collected over a thirty year period at various stations in Ontario (MacIver 1984). Although areas in the NC Region show equal or greater yearly precipitation, summer precipitation is generally greater in the NW Region. The mean ^R annual and summer temperatures also tend to be higher in the NW Region. The greater degree of jack pine seeding success in NW Region has been attributed to weather conditions more conducive to germination and survival (Brown 1974). The areas east of Lake Nipigon and along the north shore of Lake Superior have generally reported poor success with direct seeding of jack pine; the influence of climate differences on black spruce seeding is unknown.

Early spring sowing on the snow is superior to fall sowing (Brown 1974; Hellum 1974) depending on post-sowing weather conditions. Haavisto and Winston (1974) have shown that black spruce seed will germinate at $0.5^{0}C$, and may therefore start to germinate while on or under the snow in spring. Warm temperatures following snowmelt, as is often the case in the NW Region, will allow for rapid establishment. However, late spring frost periods such as often occur in the NC region may damage imbibed seeds and germinants.

Further seeding trials and a review of local weather patterns are necessary to determine the optimum seeding time for a given area. Additional work is required on the importance of

weather as a seeding variable, climatic cycles and predicting when good moist springs may occur which would favour successful black spruce seeding. The literature indicates that for most areas, sowing in early spring or in late fall produces the best results (Scott 1970; Brown 1974; Hellum 1974; Richardson 1974; 1981).

SITE SELECTION AND PRESCRIPTIONS

When considering logging and regeneration operations, most foresters recognize the basic divisions of uplands (mineral soil) and lowlands (organic soil). Finer subdivisions of these broad classes are required on which to base silvicultural prescriptions.

A Forest Ecosystem Classification (FEC) system has been developed for northwestern Ontario and to date 38 Vegetation Types and 22 Soil Types have been identified and tentatively grouped into 11 main "Treatment Units" (Sims 1988; Sims and Baldwin 1988; Sims et al. 1988). Treatment Units are groupings of stand and soil/site conditions which have similar perceived ecological and productivity characteristics. The FEC system will provide a common framework for site classification and silvicultural prescriptions in northwestern Ontario.

The Treatment Units currently proposed for northwestern Ontario indicate that black spruce direct seeding could be implemented on the Lowland Black Spruce (V34-37), Jack Pine or Black Spruce - Feather moss on Uplands (V20,28,30,32,33), Low Shrub and Herb-Rich Black Spruce (V11,19) and the Black Spruce and Jack Pine On Very Shallow Soils (V31) (Jeglum and Haavisto 1988, pers.

comm.). Seeding may not be feasible on all Vegetation Types within these groups, and the considerable range of soil types, moisture regimes and drainage will dictate specific harvesting, site preparation and seeding methods. For example, seeding with shelters may be the only effective method to ensure seeding success on the well drained upland sites (V19, V20, V31, V32, V33). Treatment units which are in the fresh to moist range of moisture regimes will provide the greatest change for successful black spruce seeding. The dry upper end of the fresh regime has less probability of success with black spruce than do the lower fresh and moist conditions.

SUMMARY AND CONCLUSIONS

Poor performance of seeded black spruce, especially when compared to jack pine, has reduced seeding to a minor role in the black spruce regeneration effort in northwestern Ontario. Many failures of black spruce seeding can be attributed to poor seedbed selection, site preparation, weather, rodents and quantity of seed applied.

To make black spruce seeding a viable regeneration option, the following must be considered :

1. Seeding of black spruce should be considered only for the poorer, less accessible and less intensively managed sites.

2. Uplands Sites
   a) Site preparation for seeding black spruce on upland sites should create a mixture of mineral soil and humus. This is best for black spruce germination and subsequent seedling survival and growth. Prescribed burning can achieve a favourable seedbed if a moderate to hot burn can consume most of the organic layer. Mechanical site preparation for black spruce seeding has not been effective, although the careful use of the power head disc trencher appears promising.
   b) Shelter seeding is the only consistently successful method of seeding black spruce on upland sites. Shelter cones can greatly improve black spruce stocking and make

more efficient use of its limited seed. Seeding should commence as early in the spring as possible, at a rate of 4 to 6 viable seeds per shelter.

c) Black spruce direct seeding can be considered on uplands on the following Forest Ecosystem Classification (FEC) vegetation types: Jack Pine or Black Spruce - Feather moss on Uplands (V20, 28, 30, 32, 33) Low Shrub and Herb-Rich Black Spruce (V11, 19) and Black Spruce and Jack Pine on Very Shallow Soils (V31).

3. Lowland Sites

a) Full tree logging with wide-tracked skidders or careful logging to preserve advance growth should be considered on lowland sites that are to be direct seeded.

b) Sphagnum moss and well decomposed organic matter (dark peat) provide good seedbeds for black spruce seeding. On sphagnum-rich sites, slash removal may be all that is required. Full tree logging and harvesting with wide-tired machines can maintain and improve the sphagnum seedbed. Where sphagnum or dark peat seedbeds are not prevalent (i.e. feather moss sites), winter shear blading or prescribed burning should be considered.

c) Spot seeding is the preferred seeding method on lowland sites. Broadcast seeding on lowlands in northwestern Ontario still requires further research and development.

d) Black spruce seeding can be considered on the Lowland Black Spruce FEC vegetation types V34 to V37.

4. Research and Development

Many of the techniques reported in the literature are applicable to northeastern Ontario but have not been adequately tested or applied in northwestern Ontario where climate and sites are much different. Further trials to determine the optimum sites, seeding rates, seeding methods and climatic influences are required in northwestern Ontario.

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